# GEOLOGIC ATLAS OF THE UNITED STATES

## ESTILLVILLE FOLIO, KENTUCKY-VIRGINIA- TENNESSEE

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

# GEOLOGIC ATLAS

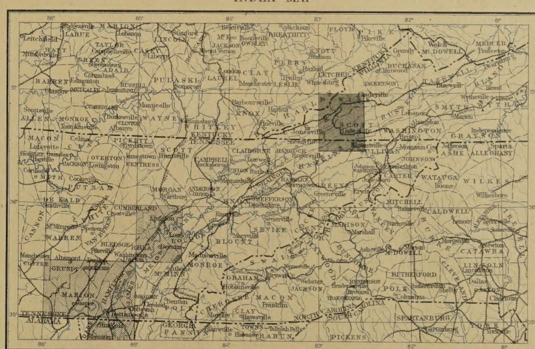
## OF THE

# UNITED STATES

# ESTILLVILLE FOLIO

## KENTUCKY - VIRGINIA - TENNESSEE

INDEX MAP




SCALE: 40 MILES - 1 INCH

AREA OF THE ESTILLVILLE FOLIO

AREA OF OTHER PUBLISHED FOLIOS

## LIST OF SHEETS

DESCRIPTION — TOPOGRAPHY — AREAL GEOLOGY — ECONOMIC GEOLOGY — STRUCTURE SECTIONS

COLUMNAR SECTIONS



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# EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

## THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages and cities.

*Relief.*—All elevations are measured from mean sea level. The heights of many points are accurately determined and those which are most important are stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

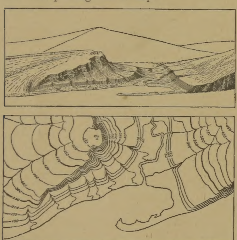

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and so on with any other contour. In the space between any two contours occur all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines and define all prominences. The relations of contour characters to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$, the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

*Drainage.*—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

*Culture.*—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

*Scales.*—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$, to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

*Atlas sheets.*—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree These areas correspond nearly to 4000, 1000 and 250 square miles.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the states, counties or townships. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

## THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes. The Appalachian mountains would become an archipelago in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses; and as it rises or subsides the shore lines of the oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

| PERIOD. | SYMBOL. | COLOR—PRINTED IN PATTERNS OF PARALLEL LINES. |
|---|---|---|
| Neocene (youngest). | N | Yellowish buff. |
| Eocene | E | Olive-brown. |
| Cretaceous | K | Olive-green. |
| Juratrias | J | Gray-blue-green. |
| Carboniferous | C | Gray-blue. |
| Devonian | D | Gray-blue-purple. |
| Silurian | S | Gray-red-purple. |
| Cambrian | Є | Brown-red. |
| Algonkian (oldest). | A | Orange-brown. |

In any district several periods may be represented, and the representation of each may include one or many formations. To distinguish the sedimentary formations of any one period from those of another, the patterns for the formations of each period are printed in the appropriate period-color; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

# DESCRIPTION OF THE ESTILLVILLE SHEET.

## GEOGRAPHY.

*General relations.*—The territory represented by the Estillville atlas sheet is one-quarter of a square degree of the earth's surface, extending from latitude 36° 30′ on the south to 37° on the north, and from longitude 82° 30′ on the east to 83° on the west. Its average width is 27.7 miles, its length is 34.5 miles, and its area is 956.6 square miles.

By State boundaries this territory is divided into three parts: the southern part includes portions of Hancock, Hawkins, and Sullivan counties, Tennessee; the middle, portions of Wise, Scott, and Lee counties, Virginia; and the northern, portions of Harlan and Letcher counties, Kentucky. Passing from north to east, the adjacent atlas sheets are as follows: Whitesburg, Grundy, Bristol, Roan Mountain, Greeneville, Morristown, Jonesville, and Hazard.

In its geographic and geologic relations this area forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that covered by a single atlas sheet; hence it is necessary to consider the individual sheet in its relations to the entire province.

*Subdivisions of the Appalachian province.*—The Appalachian province may be subdivided into three well-marked physiographic divisions, throughout each of which certain forces have produced similar results in sedimentation, in geologic structure, and in topography. These divisions extend the entire length of the province, from northeast to southwest.

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. It coincides with the belt of folded rocks which in the southern portion of the province forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee. Throughout the northern and central portions the eastern side only is marked by great valleys, such as the Shenandoah Valley of Virginia and the Cumberland and Lebanon valleys of Maryland and Pennsylvania, while the western portion is but a succession of narrow ridges with no continuous or broad intermediate valleys. This division varies in width from 40 to 125 miles. It is sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Alleghany Mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The strata, which must originally have been nearly horizontal, now stand at various angles and intersect the surface in narrow belts. With the outcrop of different kinds of rock the surface changes, so that sharp ridges and narrow valleys of great length follow the narrow belts of hard and soft rocks. Owing to the large amount of calcareous rock brought up on the steep folds of this district, its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

The eastern division of the province embraces the Appalachian Mountains, a system made up of many individual ranges, which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Many of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates and schists by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

The western division of the Appalachian province embraces the Cumberland Plateau and the Alleghany Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as coinciding with the Mississippi River as far up as Cairo, and thence extending northeastward across the States of Illinois and Indiana. Its eastern boundary is sharply defined by the Alleghany front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin, and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level.

*Altitude of the Appalachian province.*—The Appalachian province as a whole is broadly arched, its surface rising from an altitude of about 500 feet along the eastern margin to the crest of the Appalachian Mountains, and thence descending westward to about the same altitude on the Ohio and Mississippi rivers.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they decrease to 4,000 or 3,000 feet in southern Virginia, rise to 4,000 feet in central Virginia, and descend to 2,000 or 1,500 feet on the Maryland-Pennsylvania line.

The Appalachian Valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2,000 feet at the Tennessee-Virginia line, and 2,500 or 2,700 feet at its highest point, on the divide between the New and Tennessee rivers. From this point it descends to 2,200 feet in the valley of New River, 1,500 to 1,000 feet in the James River basin, and 1,000 to 500 feet in the Potomac basin. Throughout Pennsylvania it maintains about the same elevation as in the Potomac basin. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2,000 feet.

The plateau, or western, division increases in altitude from 500 feet at the southern edge of the province to 1,500 feet in northern Alabama, 2,000 feet in central Tennessee, and 3,500 feet in southeastern Kentucky. It is between 3,000 and 4,000 feet high in West Virginia, and descends to about 2,000 feet in Pennsylvania. From the eastern edge the plateau slopes gradually westward, although it is generally separated from the interior lowlands by an abrupt escarpment.

*Drainage of the Appalachian province.*—All of the western, or plateau, division of the province, except a small portion in Pennsylvania and another in Alabama, is drained by streams flowing westward to the Ohio. The northern portion of the eastern, or Appalachian Mountain, division is drained eastward to the Atlantic, while south of New River all except the eastern slope is drained westward by tributaries of the Tennessee or southward by tributaries of the Coosa.

The position of the streams in the Appalachian Valley is mainly dependent upon the geologic structure. In general they flow in courses which for long distances are parallel to the mountains on either side, following the lesser valleys along the outcrops of the softer rocks. These longitudinal streams empty into a number of larger, transverse rivers, which cross one or the other of the barriers limiting the valley. In the northern portion of the province these transverse rivers are the Delaware, Susquehanna, Potomac, James, and Roanoke, each of which passes through the Appalachian Mountains in a narrow gap and flows eastward to the sea. In the central portion of the province these longitudinal streams form the New (or Kanawha) River, which flows westward in a deep, narrow gorge through the Cumberland Plateau into the Ohio River. From New River to northern Georgia the valley is drained by tributaries of the Tennessee River, which at Chattanooga leaves the broad valley on its westward course to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

*Topography of the Appalachian province.*—The different divisions of the province vary much in character of topography, as do also different portions of the same division. This variation of topographic forms is due to several conditions, which either prevail at present or have prevailed in the past. In the Appalachian Valley, differences in rock character and in geologic structure are the conditions which chiefly govern erosion. In the Appalachian Mountains and the Cumberland Plateau, structure plays but a secondary part, and the rocks are frequently so nearly homogeneous as to have but little effect on the topography. Throughout the entire province the forms produced are largely controlled by the altitude of the land, which varies in relation to sea-level as the surface is worn down by erosion or is uplifted by movements of the earth's crust. If the land is high the streams descend rapidly to the sea, corrading narrow gorges nearly to the baselevel of erosion. By lateral corrasion these narrow gorges are gradually widened and the sides reduced from precipitous cliffs to gentle slopes. The divides between adjacent streams are, little by little, worn away, and the surface gradually approaches baselevel and becomes a peneplain. But this process is carried to completion only in case there is a constant relation of land and sea. This relation may be changed by earth movements which either raise or lower the land. When erosion is thus interrupted in any stage of its development, some of the characteristic topographic forms remain among features of later development, and they constitute a record of the conditions to which they belonged. Since the close of the Paleozoic era, two well-marked peneplains have been produced in the Appalachian province. The earlier and more extensive of these peneplains was formed in the Cretaceous period, and the time during which the earth's crust was free from movement was so great that the surface was worn down to an almost featureless plain. This process was interrupted by earth movements which raised the surface far above its former position, but the elevation was unequal and the surface was greatly warped. In the ensuing Eocene, and possibly the early Neocene, a second peneplain was formed, but the time during which the relation of land and sea remained constant was short, and only the softer rocks were worn down to the baselevel of erosion. Again the process was interrupted by elevation; the surface warped as it rose; and the second peneplain, in its deformation, resembles the first. The more recent history of the province is one of general elevation accompanied by oscillations which have at various epochs allowed the sea to transgress upon the land and then again lifted the latter above its present level. During this time the modern river gorges were cut and much of the present low-level topography was produced.

*Topography of the Estillville area.*—This sheet includes portions of the Cumberland Plateau and of the Appalachian Valley. The topography of the plateau is well illustrated by the forms found in the syncline north of Stone and Powell mountains, while that of the valley is exhibited in the succession of parallel ridges shown in the southern portion of the sheet.

The highest summits on this sheet were low ridges in Cretaceous time; the even crests of the valley ridges are the scattered remnants of the early peneplain; and the present valleys are portions of the later plain. Only two areas remain that were not reduced to the baselevel of erosion during Cretaceous time. One of these is the eastern end of Powell Mountain, culminating in High Knob, 4,188 feet above sea-level; the other area is Big Black Mountain, reaching over 4,100 feet in altitude. The Cretaceous peneplain is almost completely destroyed by erosion, so that its surface is represented now only in the crests of the higher ridges. In the southern portion of the sheet, the plain formerly extended probably from the even crest of Clinch Mountain to the summit of Bays Mountain, south of Kingsport. Northwest of Clinch Mountain the ridges are less regular, and therefore they define less precisely the position of the plain, but there is a general agreement among the high points on Wallin Ridge, the even crest of Stone Mountain, and the summit of Powell Mountain west of Slemp Gap. Beyond Big Black Mountain, with its irregular crest, is the even summit of Pine Mountain, planed down to the general height of the valley ridges. The peneplain was originally very nearly horizontal, but it has been tilted, so that now it varies in elevation from 2,400 feet in Pine Mountain to 1,700 feet in Bays Mountain.

The second, or Cenozoic, peneplain appears only in the limestone areas, in which broad valleys were eroded nearly to baselevel. The most important are the valleys of the Holston, Clinch, and Powell rivers. In these, only the softest limestones were reduced to baselevel. Shales and cherty limestones were not worn down to the level of the plain, but stood above it as low, rounded knobs or ridges. Sandstones suffered but little reduction, and remained in ridges whose summits mark the altitude of the Cretaceous plain. In the later plain the streams have cut narrow channels, which are deepest in the northwestern part of the region. Thus, Clinch River is sunk from 300 to 500 feet below its baseleveled valley, while the Holston has cut not more than 150 feet into its valley plain. The valley of Powell River has been elevated even more than that of Clinch River, but the volume of water in the stream has not been sufficient to keep pace with the uplift and its modern channel is cut but little below the old plain. In the coal field north of Stone Mountain, owing to the homogeneity of the strata, the various episodes of geologic history have left but slight record, and it is impossible to read it with certainty.

*Drainage.*—Almost all of the territory lying within the States of Virginia and Tennessee belongs to the Tennessee watershed. The largest branch of the Tennessee River is the Holston, which enters this territory at the southeastern corner, passes around the northeastern end of Bays Mountain, and leaves the area at the center of its southern border. Its only important tributary within the area of this sheet is the North Fork, which, heading some distance to the northeast, flows along the southern base of Clinch Mountain and enters the main stream just below Kingsport. Big Moccasin Creek, a branch of the North Fork, is noteworthy, since it has cut the only water gap in Clinch Mountain in a distance of 150 miles.

Between Clinch and Powell mountains the drainage is almost entirely confined to Clinch River, which, entering on the eastern side, crosses the territory diagonally to the southwest. In this region it has three large tributaries: North Fork, Copper Creek, and Guest River. North Fork has its source at the county line between Powell Mountain and Wallin Ridge, and flows in general southwest, joining Clinch River just west of the limits of the sheet. Copper Creek, rising east of the Estillville-sheet area, flows nearly west, between the river and mountain, joining the main stream at Speer Ferry. Guest River, heading north of this territory, flows south to Norton, thence east around the end of Powell Mountain, and joins the Clinch River about 10 miles beyond the eastern limit of the sheet. Stock, Stony, and Cove creeks are small streams heading in Powell Mountain and uniting with the river above Clinchport. Through the limestone ridge north of Clinchport Stock Creek has cut an interesting tunnel, whose southern entrance is picturesque, consisting of a magnificent portal opening from a wild and rugged ravine. The tunnel is now utilized by the South Atlantic and Ohio Railroad, and is an important scenic feature of that route.

Powell River, the smallest tributary of the Tennessee in this section, follows an irregular course from near Norton southwestward through Big Stone Gap and Powell Valley far beyond the limits of this sheet. It has no large tributaries in this territory; Callihan, Little Looney, and Pigeon creeks, and Roaring, South, and North forks are the most important branches. The last drains the portion of Lee County north of Stone Mountain, and emerges through Pennington Gap a few miles west of Cynthia.

Big Sandy River is represented by Steele Fork, a small creek rising on the mesa east of Gladeville and flowing north into Russell Fork.

The Kentucky portion of the Estillville-sheet area is drained entirely by the Cumberland River. Its main head branch, Poor Fork, rises near the northern edge of the sheet and flows west along the southern base of Pine Mountain. Its principal tributaries are Clover Lick, Clover Fork, and Big Looney and Lewis creeks, each flowing in narrow, sharply cut valleys, above which the mountain summits tower from 1,000 to 2,500 feet.

## GEOLOGY.

### STRATIGRAPHY.

*The general sedimentary record.*—All of the rocks appearing at the surface within the limits of the Estillville atlas sheet are of sedimentary origin—that is, they were deposited by water. They consist of sandstone, shale, and limestone, having an average total thickness of 17,000 feet and presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals which lived while the strata were being laid down.

These rocks afford a record of almost uninterrupted sedimentation from early Cambrian to late Carboniferous time. Their composition and appearance indicate at what distance from shore and in what depth of water they were deposited. Sandstones marked by ripples and cross-bedded by currents, and shales cracked by the sun, indicate shallow water and mud flats; while limestones, especially by the fossils they contain, indicate greater depth of water and scarcity of sediment. The character of the adjacent land is also shown by the character of the sediments derived from its waste. Coarse sandstones and conglomerates, such as are found in the Upper Silurian and Carboniferous, were derived from high land on which stream grades were steep; or they may have resulted from wave action as the sea encroached upon a sinking coast. Limestones are formed either in the moderate depths of the ocean or in shallow water when the adjacent land is near baselevel and the streams are too sluggish to carry much sediment, except that which is in solution. Such a period is favorable to rock decay and to the accumulation of deep residual soils in which oxidation is very complete. When the land is again elevated the red residuary products are swept into the sea, probably giving rise to the rocks of that color—red sandstones and shales near shore, and red argillaceous limestones farther out from the source of supply.

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin, but it probably varied from time to time within rather wide limits.

### CAMBRIAN STRATA.

*Russell formation.*—The lowest rocks known in this field contain the Olenellus fauna, and consequently are of Lower Cambrian age. On Copper Creek, where these fossils occur, the formation consists of thin-bedded sandstone and sandy shale, graduating upward into brown, argillaceous shale, and finally into the great mass of calcareous strata which forms the top of the Cambrian series. The Russell formation is the lowest, and since its base is not exposed, its thickness can not be determined. About 1,000 feet of alternating shale, sandstone, and impure limestone are visible at many points in this region, but the strata are adjacent to the great fault lines, and the true sequence of the beds can not be ascertained. The top of the formation usually consists of brown, argillaceous shale, growing more sandy below and varying in thickness from 200 to 600 feet. This shale attains its maximum development north of Clinch River. South of this river there is a rapid transition from the limestone above to the sandy shale and thin-bedded sandstone below. In the vicinity of Fairview the lower portion of the formation contains many beds of dark, impure ferruginous limestone, which on weathering produces a bright-red soil. This formation is everywhere well marked and easily distinguishable by its topography. Its sandy beds give rise to sharp, comby ridges, which stand up in striking contrast to the low, rounded knobs about them.

*Rutledge limestone.*—Immediately overlying the brown, argillaceous shale is the Rutledge limestone, which attains a thickness of from 200 to 240 feet. Its upper portion is a very dark, impure magnesian limestone, but its base is quite siliceous, containing many thin beds of sandy shale. It is not so soluble as the limestone above, and not so easily eroded as the brown shale immediately beneath; consequently it forms low ridges or rounded knobs, which are a marked but not a striking feature of the Cambrian valleys. This formation takes its name from the town of Rutledge, Grainger County, Tennessee, where it is well developed.

*Rogersville shale.*—Over most of the area this formation is well exposed and is a reliable guide to the stratigraphy. It is a blue, calcareous shale, abundantly fossiliferous, and remarkably persistent over a large area of northeastern Tennessee. It varies in thickness from 80 to 120 feet, and outcrops either in the bottom of the Cambrian valleys or upon the backs of the low ridges formed by the Rutledge limestone. In Carter Valley east of Cloud ford this formation becomes a dark, siliceous limestone, which can not be separated from the limestones above and below. The shale is named from Rogersville, Hawkins County, Tennessee.

*Maryville limestone.*—Wherever this formation occurs in this district it is a comparatively pure, heavy-bedded, blue limestone. In the southeastern portion it carries large masses of chert, which appear on the surface in rudely spherical bodies, deeply stained by impregnation of iron. These cherts are with difficulty separated from those of the Knox dolomite, but their peculiar shape, together with their stained surface, will generally serve to distinguish them. The thickness of this limestone varies from 550 to 650 feet. It is named from Maryville, Blount County, Tennessee.

*Nolichucky shale.*—Above the Maryville limestone occurs a bed of calcareous shale varying in thickness from 500 to 730 feet. In Carter Valley, the center of the formation, is a lentil of massive, blue limestone, which attains a maximum thickness of 400 to 500 feet. The shale usually crops out along the northern side of the areas of Knox dolomite, and since it is less resistant than the dolomite, it forms the steep northern slopes of those ridges. Its name is derived from the Nolichucky River, along whose banks it outcrops for many miles.

The foregoing formations constitute the Cambrian rocks as they generally appear in this section. Lithologically they may be divided roughly into two groups: an arenaceous group at the base, comprising the Russell formation, and a calcareous group, embracing the Rutledge limestone, Rogersville shale, Maryville limestone, and Nolichucky shale. These two groups are probably nearly equivalent to the Rome formation and the Connasauga shale of northern Georgia and southern Tennessee, described in the Kingston, Chattanooga, and Ringgold folios. That these two groups include all of the rocks of Cambrian age is doubtful, since a recent discovery of fossils in the Knox dolomite indicates that a portion of that great formation also belongs to the Cambrian period.

### CAMBRO-SILURIAN STRATA.

*Knox dolomite.*—Above the Nolichucky shale occurs the greatest limestone formation known in the province. This was early named by Safford the Knox dolomite, from Knox County, Tennessee, and in the Estillville area it retains the principal features which characterize it in the type locality. Its lower portion is probably of Cambrian age, while its upper portion is certainly Silurian. No line of division can be drawn in the limestones, and hence the whole is considered a unit of Cambro-Silurian age. It is generally a gray magnesian limestone, or dolomite, occurring in thick beds, and is usually covered on its outcrop by a heavy mantle of residual chert. The cherts occur as flattened nodules in the limestone, and are usually white in color and very dense; but sometimes they are composed of grains of silica or oolites in the form of a very porous sandstone. The cherts in the upper thousand feet of the formation are frequently fossiliferous, containing forms of Calciferous age.

In this area the formation varies in thickness from 2,100 to 3,000 feet, being much thinner than it usually is in East Tennessee. The minimum (2,100 feet) was obtained in a carefully measured section where Clinch River cuts the Big or Copper Ridge, south of Clinchport. The top of the formation is here clearly defined by a white, argillaceous limestone immediately underlying the blue, fossiliferous Chickamauga limestone, and the base is equally well marked by a black, sandy limestone in contact with the Nolichucky shale. Since the dips (42°) are regular throughout, and the exposures almost continuous, the result can hardly be questioned. Within a mile of this section occurs a conglomerate of rounded pebbles of chert in a dolomite matrix, which, if interpreted aright, marks a plane of unconformable deposition. After a portion of the dolomite had been deposited, it was raised above the level of the sea. This elevated area was subjected to erosion, and an indefinite amount was removed from the surface of the land, along the shore of which the cherty conglomerate formed. Again the land sank below the level of the sea, when deposition of the dolomite was resumed under conditions so nearly like those existing before the uplift that no visible unconformity can be found. The reduced thickness of the formation and the cherty conglomerate are the only remaining evidences of this interruption in the deposition.

### SILURIAN STRATA.

*Chickamauga limestone.*—Above the white, argillaceous limestone at the top of the Knox, comes a series of blue, flaggy limestones, known as the Chickamauga, from the valley of Chickamauga Creek in Walker and Catoosa counties, Georgia. During the deposition of the Knox dolomite the land area southeast of the Appalachian Valley probably was reduced to a low peneplain, from which but little sediment was carried to the sea. With the inauguration of the Chickamauga epoch the conditions changed; for the sediments indicate that, in consequence of elevation of the land, erosion was very active and the streams carried to the sea an immense amount of material worn mechanically from the land. The coarsest material was deposited near shore; fine sand and mud were carried farther out; and finally, beyond the influence of shore conditions, limestones were formed upon the bottom of the sea. Thus the limestone, which in Powell Valley can not be less than 1,800 feet in thickness, is but 300 or 400 feet thick in the valley of the Holston, and probably disappears altogether farther southeast. The transition from the shore phase of sandstone and sandy shale to the deep-sea deposit of pure limestone is shown by a group of earthy limestones, which have been mapped as the Moccasin formation. Almost all of the noted valleys of the Appalachians owe their fertility to the outcrop of the Chickamauga limestone. It also carries the famous marbles of East Tennessee, a small area of which falls within the limits of this sheet.

*Moccasin limestone.*—Between the great development of Chickamauga limestone in Powell Valley and the equally great development of shale in the Bays Mountain syncline is the transition rock—the argillaceous limestone named as above from its occurrence on Moccasin Creek. It is a red, argillaceous limestone, passing into the blue, flaggy Chickamauga limestone below and into the blue and yellow Sevier shale above, being intermediate between the deep-sea deposits of the northwestern portion of the sheet and the arenaceous shore deposits of the Bays syncline. This formation attains its maximum thickness along Clinch Mountain, where it averages about 500 feet.

*Sevier shale.*—This great mass of muddy sediments exhibits a wonderful increase in thickness toward the southeast, showing that the source of the material was in that direction, and probably at no great distance. Its name is derived from Sevier County, Tennessee, where it is well exposed in the gray shale hills for which that region is noted. In Powell Valley this shale is 400 or 600 feet in thickness, varying in character from calcareous shale at the base to very sandy shale at the top. Along Clinch Mountain the same arrangement is found, but the thickness has increased to 1,200 or 1,500 feet. Southeast of Clinch Mountain these rocks have been eroded, except in the Bays syncline, in which they attain their greatest thickness—more than 3,000 feet. The base is generally a black shale, varying from a few feet in thickness on the northern side of Bays Mountain to 500 or 800 feet on the southern side. Above the black shale is an indefinite thickness of blue and yellow shale, becoming more sandy toward the upper portion of the series, though carrying many beds of limestone even near the top. Owing to structural complications, it is exceedingly difficult to determine the thickness of this formation, but the average of several sections in the Bays Mountains is 4,000 feet.

*Bays sandstone.*—The Sevier shale is overlain by a red sandstone or sandy shale, which varies from 140 to 350 feet in thickness. Its maximum development occurs near the center of the sheet, from which it diminishes toward both the northwest and the southeast. In the northwestern corner of the sheet, where the Clinch sandstone is absent, the Bays sandstone forms sharp ridges or serrate knobs, but it is generally less prominent than the harder sandstone above it, and appears only on the steep northwestern slopes of the valley ridges. This formation takes its name from the Bays Mountain, south of Kingsport.

*Clinch sandstone.*—Of all the Silurian formations, the most important in its effect upon the topography of the region is the Clinch sandstone, which, through superior hardness, has withstood erosion more successfully than the adjacent formations; consequently it forms the highest of the valley ridges. This sandstone attains a thickness of 500 feet on Clinch Mountain, from which it derives its name. It diminishes to 300 feet in the Bays Mountain, and northwestward it disappears entirely in Powell Valley near the western edge of the sheet. It is generally one massive bed of coarse, white sandstone, but in Bays Mountain it is divided into a number of heavy beds, with bright-red shales between. The ridges formed by this sandstone are Bays, Clinch, and Powell mountains and Wallin Ridge.

*Rockwood formation.*—Above the heavy Clinch sandstone occur shales and sandstones of variable thickness and composition. In Powell Valley the formation is from 400 to 600 feet in thickness, while on Clinch Mountain it is probably less than 100 feet thick. Where it attains its maximum, along Stone Mountain, it forms the so-called Poor Valley Ridge—a low, irregular line of knobs along the foot of the mountain. South of this it has but little influence on the topography, since it outcrops only on the slopes of the Clinch sandstone ridges.

*Rockwood sandstone.*—In the syncline south of Clinch Mountain there is a heavy sandstone at the top of the formation just described. It is always coarse, frequently conglomeratic, and from 15 to 20 feet in thickness. It has not been found farther southwest than Little War Gap, near the western edge of the area, where it is 10 or 12 feet thick. Toward the northeast, however, it thickens rapidly and becomes a persistent and prominent member separating two important iron-bearing strata. For this reason it is desirable to show its outcrop on the regular geologic map, although it is only a lentil of coarse sandstone at the top of the series.

The entire formation takes its name from Rockwood, Roane County, Tennessee, where it has furnished ores for commercial use for twenty-five years. The upper bed is called the Rockwood sandstone.

*Hancock limestone.*—This formation is practically limited to the region northwest of Clinch Mountain, and is named from Hancock County, Tennessee. From a maximum of 275 feet in Powell Valley, it thins to a feather-edge toward the southeast. Its former southward extent in the western half of the sheet can not be determined, since the great folds and faults between Powell and Clinch mountains have lifted this limestone far above the present surface, and erosion has removed it. South of Clinch Mountain it is found only in the region east of Big Moccasin Gap, where it is thin and poorly exposed.

### DEVONIAN STRATA.

*Chattanooga black shale.*—Throughout most of the region south of central Tennessee this formation is less than 50 feet in thickness. At Big Stone Gap it is at least 500 feet thick, and its outcrop around Powell Mountain and the eastern end of Clinch Mountain reaches 900 feet. This may be divided into three approximately equal parts. The top and bottom consist of a fine, black, carbonaceous shale, and the middle consists of an ash-colored, sandy or micaceous shale. The black shale contains so much carbonaceous matter that it is frequently mistaken for bituminous coal. In fact, coal seams a fraction of an inch in thickness are not uncommon in the formation, but nothing

of commercial importance has ever been discovered. On weathering, the shales produce a white, tenacious clay, forming the "poor valleys" of the region.

*Grainger shale.*—Above the black shale occur strata of sandy shale and thin-bedded sandstone, which may be either Devonian or Carboniferous. They are named from Grainger County, Tennessee, and are here provisionally classed as Devonian until their fossils can be more thoroughly studied and their age determined. They vary in thickness from 400 feet in the northeastern part of the sheet to 980 feet in the southern portion. They form sharp, narrow ridges, with a "poor valley" on one side and on the other a broad valley carved in the Carboniferous limestone.

CARBONIFEROUS STRATA.

*Newman limestone.*—The base of the Carboniferous system is probably the Newman limestone, a persistent member of the great sheet of marine deposits stretching from Pennsylvania to central Alabama and thence northwestward across the Mississippi basin. At Big Stone Gap the formation is 930 feet thick, and is composed in its upper part of calcareous shale, graduating downward into shaly limestone and hard, blue, cherty limestone. In the Clinch syncline its thickness is at least 1,500 feet, but the same arrangement of sediments prevails. This limestone usually produces valleys, but along the northern face of Powell Mountain, in the vicinity of Big Stone Gap, it forms a line of very bold and rugged cliffs. The formation receives its name from Newman Ridge, Hancock County, Tennessee.

*Pennington shale.*—This formation, named from Pennington Gap, Lee County, Virginia, is made up of calcareous and argillaceous shale, a few beds of impure limestone, and heavy sandstone. Its base is quite calcareous, but its top is composed of red and purple shale, carrying locally thin seams of coal. Its thickness along Stone Mountain, where it is best exposed, is about 1,100 feet. In the Clinch syncline east of Big Moccasin Gap, only the base of this formation is preserved, consisting of thin sandstones and sandy shale, a few hundred feet in thickness.

*Lee conglomerate.*—The base of the Coal Measures in this region consists of a conglomerate member, which is exceptionally thick and complex. It is named from Lee County, Virginia, where it is well exposed in the southern face of the Cumberland escarpment. Its maximum thickness of 1,530 feet is attained at Big Stone Gap, from which place it decreases toward the northwest to 1,200 feet near the northwestern corner of the territory. This formation is composed of three beds of massive sandstone or conglomerate, separated by intervals of shale, the whole carrying from two to six seams of coal. The massive sandstone, or Bee rock, forming the top of the series, is about 100 feet in thickness, and makes conspicuous topographic features at the head of every gap through the ridge. The basal member is usually the coarsest, being a mass of rounded quartz pebbles from the size of a pea to an inch in diameter. The formation is the most resistant one in this region, and consequently makes the most pronounced ridges. Where it has been sharply upturned it forms the monoclinal ridges of Pine and Stone mountains; where it lies nearly horizontal it protects the measures below from rapid erosion and produces mesas and broad mountain summits, as in Powell Mountain, near the eastern edge of the area. No trace of the Lee conglomerate has been discovered southeast of the Hunter Valley fault, and therefore its original extent in that direction is problematic. It attains its greatest development along the southeastern side of the coal field, which seems to indicate the proximity of a former shore-line in that vicinity.

*Norton formation.*—Above the Lee conglomerate is a mass of coal-bearing sediments, about 1,280 feet in thickness, consisting of shales, coals, and sandstones, which are here grouped together as one formation and named from the town of Norton. The upper limit of the formation is the base of a massive sandstone, which is well exposed about Gladeville, in Wise County. The coal seams, which are most important in this formation, show a peculiar stratigraphic and geographic arrangement. In the eastern portion of the field, near Tacoma, the principal seams lie within a few hundred feet of the Lee conglomerate; in the vicinity of Big Stone Gap they are near the top; and on the Poor Fork, in Kentucky, it is doubtful whether this formation contains any workable seams. The Norton formation has two principal lines of outcrop, one along the northern base of Stone Mountain and the other along the southern base of Pine Mountain.

*Gladeville sandstone.*—From the top of the Lee conglomerate to the base of the Harlan sandstone, capping Big Black Mountain, there is a succession of shales, coals, and sandstones, 2,600 or 2,700 feet in thickness, which can be separated into formations only with the greatest difficulty. In such a great series, carrying many valuable coal seams, a stratum which can be recognized throughout the field is an important aid to the correlation of the coal seams. The Gladeville sandstone, occurring about the middle of this series, is the only stratum which thus far has been identified over a wide area, and consequently it is worthy of close study by all who are interested in the structure and stratigraphy of the field. It is a very coarse sandstone, from 100 to 120 feet in thickness, and is generally thick-bedded. In the region about Gladeville—from which it derives its name—it is approximately horizontal, and forms a broad table-land about 500 feet above the level of the streams draining the region; whereas farther west it simply produces sharp, rocky knobs on the spurs of Little Black Mountain. In the Kentucky valleys it always shows in the beds of the streams as a coarse sandstone almost free from bedding planes.

*Wise formation.*—Above the Gladeville sandstone there is a mass of sediments, 1,270 feet in thickness, which is very similar to the Norton formation, except that its coal seams are neither so valuable nor so numerous. Important coal horizons occur at its base and at its extreme top, but being located far up on the slopes of the mountains, they have received little attention from prospectors. The outcrops of this formation are along the steep slopes of Big Black and Little Black mountains and are frequently masked by the heavy debris from the formation capping their summits. It is named from Wise County, Virginia.

*Harlan sandstone.*—The highest member of the geologic column in this territory is the Harlan sandstone, so named from Harlan County, Kentucky. It is composed mainly of coarse, white sandstone, but includes many beds of sandy shale and thin coal seams. Its base is particularly prominent, being an extremely massive sandstone about 40 feet thick, and forming, on some of the narrow spurs, rugged and picturesque ledges. The present thickness of this formation, measured to the highest summit of the mountain, is 880 feet. Whether this extends to the top of the Carboniferous formations is unknown, since erosion may have removed hundreds of feet of strata originally deposited upon it. The Paleozoic history of this region, so far as it is recorded in the sediments of that era, closed with the deposition of the Harlan sandstone, unless higher Carboniferous rocks have been eroded from the summit of the Big Black Mountain. Since then the region has been a land area, and its record has been written in the forms of relief sculptured upon its surface. These forms have been described under the head of Topography, where a sketch was given of the general conditions prevailing during post-Paleozoic time.

STRUCTURE.

*Definition of terms.*—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have extended in nearly horizontal layers. At present, however, the beds are usually not horizontal, but are inclined at various angles, their edges appearing at the surface. The angle at which they are inclined is called the *dip*. In the process of deformation the strata have been thrown into a series of arches and troughs. In describing these folds the term *syncline* is applied to the downward-bending trough and the term *anticline* to the upward-bending arch. A synclinal *axis* is a line running lengthwise in the synclinal trough, at every point occupying its lowest part, toward which the rocks dip on either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and away from which the rocks dip on either side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually but a few degrees. In addition to the folding, and as a result of the continued action of the same forces which produced it, the strata along certain lines have been fractured, allowing one portion to be thrust forward upon the other. Such a break is called a *fault*. If the arch is eroded and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. In folds and faults of the ordinary type, rocks change their form mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, and slipped past one another, causing *cleavage*. Extreme development of these minute dislocations is attended by the growth of new minerals out of the fragments of the old—a process which is called *metamorphism*.

*Structure of the Appalachian province.*—Each subdivision of the province is characterized by a distinctive type of structure. In the plateau region and westward the rocks are generally horizontal and retain their original composition. In the valley the rocks have been steeply tilted, bent into folds, broken by faults, and to some extent altered into slates. In the mountain district faults and folds are important features of the structure, but the form of the rocks has been changed to a greater extent by the minute breaks of cleavage and by the growth of new minerals. In the valley region the folds and faults are parallel to the old shore-line, extending in a northeast and southwest direction for very great distances. Some of these faults have been traced 300 miles, and some folds even farther. Many folds maintain a uniform size for great distances, bringing to the surface a single formation in a narrow line of outcrop on the axis of the anticline, and another formation in a similar narrow outcrop in the bottom of the syncline. The folds are also approximately equal to one another in height, so that many parallel folds bring to the surface the same formations. The rocks dip at all angles, and frequently the sides of the fold are compressed until they are parallel. Where the folds have been overturned, it is always toward the northwest, producing southeastern dips on both limbs of the fold. In the southern portion of the Appalachian Valley, where this type of structure prevails, scarcely a bed can be found which dips toward the northwest.

Out of the closed folds the faults were developed, and with few exceptions the fault planes dip toward the southeast and are parallel to the bedding planes. Along these planes of fracture the rocks moved to varying distances, sometimes as great as 6 or 8 miles.

There is a progressive increase in degree of deformation from northeast to southwest, resulting in different types of structure in different localities. In southern New York the strata are but slightly disturbed by a few inconspicuous folds. Many new folds are developed in Pennsylvania, and all are of increased magnitude, but the folds are open, and, as a rule, the dips are gentle. This structure holds as far south as central Virginia, where a few folds on the eastern side of the Great Valley have been compressed to such an extent that faulting has ensued. In southern Virginia and northern Tennessee faults become more common, and open folds are the exception. From central Tennessee to Georgia and Alabama almost every fold is broken, and the strata form an imbricated structure, in which all of the beds dip to the southeast. Throughout Alabama the faults are fewer in number, their horizontal displacement is much greater, and the folds are somewhat more open.

In the Appalachian Mountains the same structure is found that marks the Great Valley, such as the eastward dips, the close folds, the thrust faults, etc. In addition to these changes of form, which took place mainly by motion on the bedding planes, there was developed a series of minute breaks across the strata, producing cleavage, or a tendency to split readily along these new planes. These planes dip southeast, usually about 60°. As the breaks became more frequent and greater, they were accompanied by growth of new minerals out of the fragments of the old. All rocks, both sedimentary and original crystalline, were subjected to this process, and the final products of the metamorphism of very different rocks are often indistinguishable. Throughout the entire Appalachian province there is a regular increase of metamorphism toward the southeast, so that a bed quite unaltered at the border of the Great Valley can be traced through greater and greater changes until it has lost every original character.

The structures above described are manifestly the result of horizontal compression which acted in a northwest-southeast direction, at right angles to the trend of the folds and cleavage planes. The compression began in early Paleozoic time and probably continued at intervals up to its culmination after the close of the Carboniferous.

In addition to the horizontal force of compression, the province has been subjected to forces which have repeatedly elevated and depressed its surface. In post-Paleozoic time there have been at least three and probably more periods of decided oscillation of the land, due to the action of vertical forces. In every case the movements have resulted in the warping of the surface, and the greatest uplift has generally coincided with the Great Valley.

*Structure sections.*—The sections on the structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the strata are shown. These sections represent the structure as it is inferred from the position of the strata observed at the surface. On the scale of the map they can not represent the minute details of structure, and they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section.

Faults are represented on the map by a heavy, solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

*Structure of the Estillville sheet.*—The folding and faulting which took place during the Paleozoic age affected this entire territory. The compression is most apparent in the southeastern portion of the Appalachian Valley, the folds in that part of the territory being closely appressed or faulted and overthrust. The principal exception to this is the Bays Mountain syncline, which is a broad, open fold, slightly faulted on its southeastern side. This broad fold has affected the structure to the northwest as far as the Hunter Valley fault. From whichever direction the thrust was applied that folded the rocks of this region, the great mass of sediment in the Bays Mountain syncline has acted as a barrier against which the strata to the northwest were thrust or has itself been thrust forward from the southeast against the folded rocks on the northwestern side of the valley. The result is that all the folds opposite the broad part of the syncline are closely compressed and faulted, but those farther east, beyond the deepest part of the basin, are but slightly disturbed and show light southeastward dips. The folds have bent around the point of the syncline, giving rise to considerable change in the direction of the ridges.

North of the Hunter Valley fault the folds are generally open and the dips comparatively light. In the vicinity of Big Stone Gap the most prominent structural feature is the Powell Valley anticline, which originates in this territory and extends southwest as far as Rome, Georgia. Southwest of Big Stone Gap, erosion has cut deeply into the arch and no trace of the fold is shown in the topography, but to the eastward the arch is flatter and erosion has removed it only as far as Little Stone Gap. This anticline is of the regular Appalachian type, with steeply dipping strata on its northwestern side and lightly dipping, nearly horizontal rocks on its southeastern side.

Between the Powell Valley anticline and the Hunter Valley fault there formerly existed a syncline, which is now nearly obliterated by the mass of Cambrian rocks overthrust from the southern side of the fault.

Northwest of the Powell Valley anticline is the

broad Middlesboro syncline, which, from an economic standpoint, is the most important structural feature of the region. This syncline is from 12 to 15 miles broad, and is occupied by Big Black Mountain, whose summits rise 4,100 feet above sea-level and 2,700 feet above Big Stone Gap. This ridge forms the watershed between the Cumberland and Tennessee drainage basins, and its crest marks the State line between Kentucky and Virginia. The northwestern edge of this syncline originally rose in an anticlinal fold, which broke, and its southern limb, now forming Pine Mountain, was thrust upon the nearly horizontal rocks of the Kentucky basin. This fold and fault, together with Pine Mountain—the topographic feature depending upon them—disappear a short distance to the northeast in the unbroken coal fields of West Virginia.

There are six principal faults crossing this territory and extending an indefinite distance in either direction. The Hunter Valley and the Clinch Mountain faults have been traced continuously for 300 to 350 miles. Besides these principal faults, there are 16 or 17 minor ones, whose courses are either parallel to the great faults or cross the folds at various angles.

Any marked change in the strike of the folds tends to produce complications in the structure. If the change is by a broad curve the strata adjust themselves without marked disturbance, but where the trend changes abruptly one of two things must occur: either the beds on the outside of the curve must stretch and separate under the tensile strain, or the strata on the inside of the curve must buckle under the compression and finally break along the line of least resistance. This form of plication has occurred in several places where the strike of the strata changes in conformity with the lenticular shape of the Bays Mountain syncline. Thus, Clinch Mountain, entering the sheet at the southwestern corner and pursuing its normal northeastward trend as far as Speer Ferry, swings quite abruptly due east to Big Moccasin Gap. This great bend, shared by all of the strata lying south of the mountain, produced such strains that the strata lying south of Stanley Valley were buckled, forming small cross-folds at the point of greatest compression, which is on a line from Church Hill to Ela. At Ela there is a sharp fold in the massive Knox dolomite and the Cambrian strata beneath; while on Alexander Creek the compression has been severe enough to produce a slight fault. In the vicinity of Big Moccasin Gap there is a reverse bend, and again the strata on the concave side have been folded and crushed. This line of weakness, extending from Big Moccasin Gap to Clinchport, has caused three distinct folds or breaks: one in Copper Ridge, one in Moccasin Ridge, and one in Clinch Mountain. At Clinchport a transverse fault has cut entirely across Copper Ridge, the western portion being thrust northwestward almost a mile, so that the outcrop of the Knox dolomite is not continuous. In Moccasin Ridge a sharp fold has occurred, and possibly some faulting, but not enough to be noticeable. In Clinch Mountain a cross-fold and fault have determined the location of Big Moccasin Gap. On the western side of the gap the Clinch sandstone stands almost vertical, while on the eastern side it has a dip of only 25°. Into the fault thus produced in the heavy sandstone, the soft Devonian shales have been thrust, and they are now seen in outcrop throughout the whole of the gap, resting upon the Sevier shales below. Parallel to this fault and about a mile distant to the south the Grainger shale is faulted in a similar manner and the Chattanooga black shale is brought into contact with the Newman limestone.

## MINERAL RESOURCES.

The mineral resources of the Estillville area, consisting of coal, iron ore, marble, lime, and building stone, have been but slightly developed, and their value and extent are not well known.

*Coal.*—By far the most important mineral resource of this territory is coal. As stated under Structure, the Middlesboro syncline is the principal coal basin, including in this sheet an area of 225 square miles. There is a smaller basin, and one of less importance economically, in the syncline of Powell Mountain, but the coal-bearing rocks lie so high above drainage in this basin that most of the valuable coals, if they ever extended over it, have been eroded, leaving nothing over large areas but the comparatively barren Lee conglomerate. Coal of commercial importance is reported at a few points, but generally the conditions of structure or location are unfavorable for economic mining. On Stock Creek a seam 3 feet thick has been opened for local use. It is about 60 feet above the conglomerate, and shows in a number of places. On McGee Creek, on the south face of Powell Mountain, a fine seam of cannel coal has been faced up, and shows from 4 to 6 feet in thickness, but the coal is much crushed and contorted and is in poor condition to be mined. The bed occurs apparently a few feet below the conglomerate, and is the only important seam known in this area at that horizon. In general the strata along this slope of Powell Mountain are too much disturbed to render mining profitable.

In the Middlesboro syncline but little practical development has been attempted. On Little Looney Creek, a mile above Callihan, a mine is operated in a small way by the South Atlantic and Ohio Railroad Company; and the Big Stone Gap Colliery Company has opened mines on Powell River a mile above West Norton.

The workable coals occur mainly in the Norton formation, and they are found at different horizons in different portions of the field. As a rule, the lower coals are confined to the eastern part of the field and the higher ones to the western. The lowest coal of importance is about 200 feet above the conglomerate, and is exposed in the creek at Tacoma, having the following section:

| | Ft. | In |
|---|---|---|
| Coal | 0 | 2 |
| Shale | 0 | 3 |
| Coal | 0 | 7 |
| Knife-edge parting. | | |
| Coal | 1 | 8 |
| Dirty coal | 0 | 8 |
| Coal | 1 | 6 |
| Total | 4 | 10 |

Farther east it appears to split into two seams, one of which swells to a thickness of 8 or 10 feet on Russell Creek, east of this sheet, where it is mined under the name of the Jawbone seam.

From Tacoma eastward a higher coal, known locally as the Widow Kennedy seam, is very prominent. It is about 425 feet above the conglomerate, and at the old Greeno-Bodine mines, east of Tacoma, it shows a thickness of 4 feet 1 inch at the mouth of the mine. It has been abandoned, as too variable in thickness to work. This seam was opened about 10 miles east of Tacoma, where the same trouble was experienced and the mine was abandoned.

Above the Kennedy coal 260 feet is an important seam, which also occurs in workable thickness from Tacoma eastward. It is known as the Lower Banner, and at the Greeno-Bodine mines is reported as varying from 4 feet to 4 feet 10 inches in thickness. This coal may possibly extend as far west as Big Stone Gap, since a coal outcrops on Little Looney Creek at about this horizon with the following section:

| | Ft. | In. |
|---|---|---|
| Coal | 1 | 0 |
| Shale | 2 | 0 |
| Coal | 1 | 8 |
| Total | 4 | 8 |

About 110 feet above the Lower Banner occurs the Upper Banner, which is also limited to the territory east of Tacoma. At the mine east of the town its section is reported as follows:

| | Ft. | In. |
|---|---|---|
| Coal | 2 | 9 |
| Slate parting, some coal | 2 | 10 |
| Coal | 2 | 5 |
| Sandstone parting | 0 | 1 |
| Coal | 2 | 0 |
| Total | 10 | 1 |

These are the most important coal seams in the vicinity of Tacoma, and, with the exception noted, they are probably limited to the eastern portion of the territory.

The next higher coals occur in the vicinity of Big Stone Gap. The most prominent of these is the Imboden seam, which can be traced continuously from Norton to the Lee County line; but it has not been recognized in that county, nor in the Kentucky field, across the mountains. In the vicinity of the Lee County line its thickness is about 30 inches; in a small branch to the eastward it shows a thickness of 4 feet 6 inches; while still farther east a seam having the following section has been doubtfully identified as the Imboden:

| | Ft | In. |
|---|---|---|
| Coal | 1 | 0 |
| Shale | 5 | 8 |
| Coal | 2 | 0 |
| Shale | 0 | 6 |
| Coal | 3 | 6 |
| Total | 12 | 8 |

In the mine on Little Looney Creek, the Imboden seam varies in thickness from 5 to 9 feet. Where it is 5 feet thick the entire amount is solid coal, but elsewhere the seam splits into two benches, a wedge of dirty coal coming in near the center of the seam. On Preacher Creek it shows as follows:

| | Ft. | In |
|---|---|---|
| Sandstone roof. | | |
| Coal | 11 | 0 |
| Bony coal | 0 | 3 |
| Coal | 1 | 8 |
| Clay | 0 | 2 |
| Sandstone floor. | | |
| Total | 13 | 1 |

This thickness does not hold for any great distance, for on Mud Lick Creek it has the following section:

| | Ft | In. |
|---|---|---|
| Coal | 1 | 10 |
| Knife-edge parting. | | |
| Coal | 1 | 4 |
| Bony coal | 0 | 1 |
| Coal | 0 | 6 |
| Bony coal | 0 | 6 |
| Coal | 2 | 4 |
| Total | 6 | 7 |

It thickens again eastward, and shows the following section on Roaring Fork at the mouth of Whitley Fork:

| | Ft. | In |
|---|---|---|
| Coal | 1 | 6 |
| Shale | 1 | 4 |
| Coal | 2 | 2½ |
| Dirty coal | 1 | 1 |
| Coal | 1 | 1½ |
| Shale carrying sulphur | 0 | 5 |
| Coal | 3 | 2½ |
| Total | 10 | 10½ |

From this opening it thins rapidly to Black Creek, where it is about 4 feet 2 inches thick. East of this it exhibits considerable variation in thickness and character, as is shown by the following sections:

*Cooper opening, on Powell River north of Norton.*

| | Ft. | In. |
|---|---|---|
| Coal | 4 | 0 |
| Shale | 0 | 2 |
| Coal | 4 | 0 |
| Total | 8 | 2 |

*Opening 1 mile northeast of Norton.*

| | Ft | In |
|---|---|---|
| Coal | 2 | 10 |
| Clay | 1 | 0 |
| Coal | 0 | 3 |
| Clay | 0 | 6 |
| Coal | 1 | 10 |
| Clay | 0 | 8 |
| Coal | 1 | 10 |
| Total | 8 | 11 |

*Opening on Guest River at the bend east of Norton.*

| | Ft. | In. |
|---|---|---|
| Coal | 2 | 8 |
| Clay | 0 | 8 |
| Coal | 0 | 2 |
| Clay | 0 | 4 |
| Coal | 1 | 6 |
| Dirty coal | 0 | 2 |
| Coal | 0 | 5 |
| Shale | 0 | 6 |
| Coal | 2 | 8 |
| Shale | 0 | 1 |
| Coal | 0 | 4 |
| Total | 9 | 6 |

East of Norton the identification of the Imboden seam is very doubtful. If it is present it is probably well up in the hills and of insignificant thickness. The Imboden seam is a fine body of coal. It produces excellent coke and is destined to furnish fuel to many of the iron furnaces of the middle South.

Above the Imboden 50 or 75 feet is a seam of coal, known as the Kelly, which in several places attains workable thickness, but it may not be utilized, since in removing the Imboden the roof will be allowed to fall, which will effectually prevent work in this seam. It has probably its greatest development on Roaring Fork, where it shows as follows:

| | Ft. | In. |
|---|---|---|
| Shaly coal | 1 | 3 |
| Coal | 6 | 0 |
| Total | 7 | 3 |

At Pioneer, on Callihan Creek, the Kelly is but 8 or 9 inches thick, and it is generally variable throughout the field.

The next important seam is just beneath the Gladeville sandstone, or at the top of the Norton formation. On Powell River north of Norton it shows as follows:

| | Ft. | In. |
|---|---|---|
| Coal | 2 | 6 |
| Shaly coal | 0 | 6 |
| Total | 3 | 0 |

Throughout the valley of Callihan Creek this coal holds a thickness of about 2 feet, but swells to a workable seam in Lee County. It has been opened near Morris Gap, where it shows the following section:

| | Ft. | In |
|---|---|---|
| Coal | 1 | 8 |
| Knife-edge of slate. | | |
| Coal | 3 | 8 |
| Knife-edge of slate. | | |
| Coal | 1 | 4 |
| Total | 6 | 8 |

On Jones Creek its section is as follows:

| | Ft. | In. |
|---|---|---|
| Coal | 4 | 7 |
| Slate | 0 | 1 |
| Coal | 0 | 4 |
| Total | 5 | 0 |

On Clover Fork it is somewhat thinner, but on Big Looney Creek it regains its normal thickness, as the following section shows:

| | Ft. | In. |
|---|---|---|
| Coal | 0 | 6 |
| Shale | 0 | 8 |
| Coal | 4 | 3 |
| Total | 5 | 5 |

The important coals above this horizon are mainly limited to the Kentucky portion of the field. Just above the Gladeville sandstone occurs a coal which on the Virginia side is insignificant but which has a phenomenal development on Clover Lick Creek. Near the mouth of this creek the seam shows 16 feet of solid coal, but unfortunately this extreme thickness does not hold for any great distance. On Big Looney Creek, 2 or 3 miles east of the last-described exposure, it shows in a small stream, with the following section:

| | Ft. | In. |
|---|---|---|
| Coal | 0 | 6 |
| Shaly coal | 0 | 6 |
| Coal | 1 | 6 |
| Shale | 0 | 6 |
| Coal | 0 | 8 |
| Shale | 1 | 8 |
| Coal | 0 | 3 |
| Shale | 0 | 4 |
| Coal | 0 | 4 |
| Shale | 0 | 2 |
| Coal | 0 | 10 |
| Total | 7 | 3 |

Above this heavy seam three quite important seams occur in an interval of about 200 feet. The first, about 80 feet above the sandstone, is 3 feet thick on Callihan Creek; on Clover Fork near the mouth of Razor Fork, 5 feet; and on Clover Lick Creek, 5 feet 3 inches. The second, a persistent seam, is about 120 feet above the sandstone, and has obtained considerable prominence on the Virginia side under the name of the Cannel seam. On Preacher Creek its section is as follows:

| | Ft. | In. |
|---|---|---|
| Cannel shale | 0 | 4 |
| Cannel coal | 2 | 0 |
| Shale | 0 | 4 |
| Shaly coal | 0 | 4 |
| Shale | 0 | 5 |
| Coal | 0 | 5 |
| Shale | 0 | 4 |
| Coal | 3 | 4 |
| Total | 7 | 6 |

On Big Looney Creek, near its head, this seam shows only 20 inches thick, but on Clover Lick Creek it swells to 3 feet 9 inches. About 90 feet above the Cannel seam the third heavy coal occurs, showing on Callihan Creek 4 feet, and near the head of Big Looney Creek 4 feet 1 inch, in thickness.

Another coal horizon, carrying at least one seam of considerable importance, is found at the extreme top of the Wise formation. On the mountain side above the head of Big Looney Creek it is 7 feet 3 inches thick, and it probably holds nearly the same thickness throughout most of the field. Below this, 75 or 80 feet, there is possibly another workable coal, but nothing definite is known regarding it.

As seen from the foregoing sections, the field is supplied with a number of workable seams. The deep cutting of the streams and the light dip of the strata are favorable for economic mining. On the Virginia side the valleys are generally of

easy grade, affording opportunities for the construction of spurs from the main line of railroad. The Kentucky portion has at present no railroad facilities, but a feasible line of approach lies up the Poor Fork of the Cumberland River, by which the coal from the entire valley would find an outlet both to the east and the west.

*Iron ore.*—The most important ore of iron occurring in this territory is the red fossil ore, which is limited in its occurrence to the Rockwood formation. This is generally known as the Clinton ore, and is found throughout the Appalachians from New York to Alabama. It is a regularly stratified bed, which on its outcrop consists mainly of the oxide or soft ore; below drainage it is unaffected by surface water and is simply a ferruginous limestone. The soft or surface ore is much sought for on account of its high percentage of iron and the ease with which it can be mined. The hard or limestone ore is, on the other hand, difficult to mine, and carries only a small amount of iron, but is desirable for mixing with siliceous ores, since the lime renders it self-fluxing. As a result of their mode of occurrence, the soft ores are limited in quantity, whereas the hard ores extend to considerable depth.

In this territory the Rockwood formation is not everywhere ore-bearing. On the southern slope of Clinch Mountain, where the formation consists of sandy shale but little over 100 feet thick, no trace of ore could be found. On Powell Mountain west of Slemp Gap the formation is much thicker, but still no ore has been found of commercial importance. On Wallin Ridge the ore is of workable thickness east of Lovelady Gap, where it is mined to supply the furnace at Big Stone Gap, but west of Lovelady Gap it makes but a small showing in outcrop and is supposed to be too thin for commercial purposes.

Eastward from Big Moccasin Gap, the Rockwood formation carries in the shale near its top a hematite ore which in some sections becomes of workable thickness and of good quality. Little of it occurs in this territory, but it is to be looked for just beneath the Rockwood sandstone.

Limonite ores are found in almost all residual limestone clays, but only in a few places is their quantity sufficient for practical purposes. Along the Wildcat Valley these ores occur at the horizon of the Hancock limestone, and have been mined, but not to any considerable extent.

*Marble.*—The Chickamauga limestone along the northern base of Clinch Mountain carries near its bottom a variable bed of gray and red, mottled marble, and the outcrop of this limestone north of Copper Creek contains also some thin beds of gray marble. Along the principal line of outcrop the marble is extremely variable in character as well as in thickness; in places it is highly crystalline and of good color, but in most localities it is mixed with earthy matter, which detracts greatly from its strength and color. Up to this time no developments have been undertaken along this marble belt.

*Limestone.*—Limestone of almost every quality is very abundant in this region, but it has not as yet been utilized, except for local purposes. At Big Stone Gap the lower layers of the Newman limestone are quarried and used for flux in the iron furnace at that point. Lime in abundance could be produced from many of the beds of limestone if the demand would warrant the establishment of a plant. Limestone suitable for road metal is found almost everywhere, and should be used in improving the highways.

*Building stone.*—This exists in abundance in the massive sandstones of the Coal Measures and the equally massive Knox dolomite, as well as in the soft and easily ornamented marbles of the Chickamauga formation. No developments have been made in this direction except a few small quarries in the vicinity of Big Stone Gap to supply the local demand.

## SOILS.

In this territory the soils are almost as clearly differentiated as the rocks from which they are derived, and a map of the areal geology will suffice to show the general distribution of the different kinds of soil. The soils are the result of decay and disintegration of the rocks immediately beneath, except that on steep slopes the sandstones, which invariably form the crests of the ridges, strew the slopes below with their debris, giving rise to a sandy, overplaced soil. Since the rocks outcrop in narrow belts, and since they generally alternate in character, it follows that the soils derived from them will show a similar alternation in quality. Thus a belt of rich limestone soil is usually bordered on both sides by belts of stiff, clayey soil, derived from the shales, or by thin, sandy soils, from the belts of sandstone.

The coal territory in this sheet is, in an agricultural sense, the poorest area within its borders. The rocks are composed entirely of shale and sandstone, and, owing to the paucity of calcareous matter, form an extremely poor soil. Pine and Stone mountains and a large portion of Powell Mountain are practically destitute of soil. The residual material on the lower slopes is composed almost wholly of sand derived from the decomposition of the Lee conglomerate. In the syncline between these mountains the soil is more varied, but it is generally thin and predominantly sandy. The northern slope of Big Black Mountain is in places covered with a rich, black soil, but this is due more to the accumulation of vegetable matter than to the character of the underlying rocks. In some of the valleys there is a fine soil, but it is alluvial and very limited in extent.

Powell Valley, although adjoining the previously described barren region, is one of the richest portions of the Appalachian province. Its level surface is a portion of the great Cenozoic peneplain, which is here underlain by the nearly horizontal Chickamauga limestone, the best soil-producing formation in the district. This combination of circumstances has produced a country whose surface is well disposed for agricultural pursuits and whose soil is adapted to the raising of stock or the production of heavy crops of grain.

In Wallin Valley the same limestone is found, and the same rich soil, but the valley is narrower and more deeply trenched by later erosion, and is not so well adapted to agricultural pursuits.

The North Fork of Clinch River also flows in part in a broad, baseleveled valley, but the soil is far from good. The underlying rock is mainly the Chattanooga black shale, which is noted for the poor soil it produces. Where good soils are found in this valley they are invariably alluvial. In the vicinity of Fairview the Cambrian limestones have produced some areas of rich soils, but recent erosion has been so great that the old valley is entirely dissected, by far the greater portion of the surface consisting of hill-slopes so steep that but little soil can remain upon them. The immediate stream valley has some good limestone soil, and also some alluvial bottoms, but they are of small extent.

The above description is equally applicable to the entire Clinch Valley in this territory. Doubtless in the past it has been a fine, broad valley, with rich soils, but it is so deeply cut that little good soil remains. Rye Cove is about the only portion of the valley that at all resembles Powell Valley; in it the Chickamauga limestone is nearly horizontal and the surface is but little below the surface of the peneplain.

Along the northern base of Clinch Mountain there is another line of outcrop of this limestone, which gives a rich soil, but the dips are steep and the area of the outcrop is small. Clinch River Valley is traversed by several ridges of Knox dolomite, the surface of which is covered generally by a mass of broken chert, forming one of the poorest soils known. Wherever the dolomite is free from chert it affords a fine, rich soil, capable of producing abundant returns for the labor expended upon it. The Cambrian limestones and calcareous shales are much better than the cherty surface, but they seldom cover a sufficient area to be especially valuable; besides, in this valley they are generally cut into steep hill-slopes and narrow ravines.

Clinch Mountain, especially on its southern side, furnishes extremely poor soils, as does also Pine Mountain, which is composed of the sandy Grainger shale. The line of outcrop of the Newman limestone south of Pine Mountain is marked by a much better soil, but the country is rather rough and not well adapted to farming. The soil produced by the decay of this limestone is generally a stiff clay, which forms a cold soil, but one that can be greatly enriched by fertilization.

Most of the Holston Valley is well adapted to farming. The rocks immediately beneath the surface are either limestones or shales more or less calcareous, and are deeply decayed. The surface is gently rolling, forming good farming or pasture lands.

A review of the soils and of the character of the surface shows that this territory is naturally divided by Stone Mountain into two parts. That lying south of the mountain has generally calcareous soils, and, though greatly diversified by ridges and valleys, is very well adapted to agricultural pursuits. That portion lying north of Stone Mountain has sandy or clayey soils, which yield but little in return for cultivation.

MARIUS R. CAMPBELL,
*Geologist.*

TABLE OF ANALYSES OF COALS FROM THE BIG STONE GAP FIELD, DERIVED FROM THE REPORTS OF McCREATH AND d'INVILLIERS.

| Name of seam. | Stratigraphic position. | Location. | Chemist. | Water. | Volatile matter. | Fixed carbon. | Sulphur. | Ash. | Total. | Color of ash. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cannel. | 110 feet above Gladeville sandstone. | Preacher Creek. | McCreath. | 1.716 | 43.069 | 48.252 | 0.738 | 6.225 | 100.000 | Light-red. | Sample from the cannel portion of the seam. |
| | 80 feet above Gladeville sandstone. | Sang Trace Creek. | McCreath. | 2.234 | 35.571 | 58.016 | 0.749 | 3.430 | 100.000 | Light-brown. | Sample excludes parting of bony coal and slate |
| | On top of the Gladeville sandstone. | Clover Fork, 2 miles west of this territory. | McCreath. | 2.260 | 37.270 | 57.661 | 0.539 | 2.270 | 100.000 | Reddish-gray. | Two lower benches, 32 and 7 inches thick. |
| | Under Gladeville sandstone (?). | Carroll opening, on Jones Creek. | McCreath. | 1.508 | 38.602 | 48.393 | 3.077 | 8.420 | 100.000 | Red. | Sample from the upper 3½ feet of seam. |
| | Under Gladeville sandstone (?). | Bailey opening, on Jones Creek. | McCreath. | 1.206 | 41.539 | 48.274 | 3.527 | 5.460 | 100.006 | Pink. | Entire seam except slate parting. |
| Imboden. | 180 feet below Gladeville sandstone. | Mine on Little Looney Creek. | McCreath. | 1.154 | 35.346 | 60.107 | 0.643 | 2.750 | 100.000 | Salmon. | Entire seam except slate parting. |
| Imboden. | 180 feet below Gladeville sandstone. | Mine on Little Looney Creek. | McCreath. | 0.924 | 35.971 | 58.436 | 0.579 | 4.090 | 100.000 | Red. | Upper bench and 6 inches of the top of the lower bench. |
| Imboden. | 180 feet below Gladeville sandstone. | Mine on Little Looney Creek. | McCreath. | 1.400 | 33.660 | 58.365 | 0.705 | 5.870 | 100.000 | Reddish-gray. | Entire seam except parting of 3½ inches of slate |
| Imboden (?). | 180 feet below Gladeville sandstone. | Pigeon Creek. | McCreath. | 1.464 | 36.266 | 59.741 | 0.799 | 1.730 | 100.000 | Pink. | Sample from lower bench, 5 feet 2 inches thick. |
| Imboden. | 180 feet below Gladeville sandstone. | Mud Lick Creek. | McCreath. | 2.008 | 31.437 | 57.704 | 0.651 | 8.200 | 100.000 | Reddish-gray. | Entire seam. |
| Imboden. | 180 feet below Gladeville sandstone. | Preacher Creek. | McCreath. | 1.096 | 34.684 | 58.143 | 0.662 | 5.415 | 100.000 | Cream. | Entire seam. |
| Upper Banner. | 800 feet above Lee conglomerate. | Three miles east of Tacoma. | McCreath. | 0.600 | 35.795 | 57.428 | 0.652 | 5.525 | 100.000 | Red. | Entire seam except sandstone parting of 1½ inches. |
| Upper Banner. | 800 feet above Lee conglomerate. | Near Tacoma. | Prof. Potter. | 1.48 | 31.97 | 62.85 | 0.68 | 3.70 | 100.68 | | Entire seam 50 feet from surface. (Probably excludes parting.) |
| Upper Banner. | 800 feet above Lee conglomerate. | Near Tacoma. | Prof. Potter. | 2.02 | 32.18 | 60.66 | 0.90 | 5.14 | 100.90 | | Entire seam 50 feet from surface. (Probably excludes parting.) |
| Lower Banner. | 690 feet above Lee conglomerate. | Old Greeno-Bodine mine, Tacoma. | Prof. Potter. | 2.22 | 29.56 | 59.66 | | 8.56 | 100.00 | | Entire seam; 15 feet from outcrop. |
| Lower Banner. | 690 feet above Lee conglomerate. | Toms Creek, 4 miles northeast of Tacoma. | McCreath. | 1.090 | 34.145 | 59.879 | 1.081 | 3.805 | 100.000 | | 15 feet under cover. |
| Widow Kennedy. | 425 feet above Lee conglomerate. | Old Greeno-Bodine mine, Tacoma. | McCreath. | 0.840 | 33,720 | 60.006 | 0.709 | 4.725 | 100.000 | | Entire seam; 500 feet from mouth of mine. |
| Widow Kennedy. | 425 feet above Lee conglomerate. | Banner, 6 miles east of Tacoma. | McCreath. | 0.798 | 34.023 | 61.411 | 0.619 | 3.150 | 100.000 | | Entire seam; from mine. |

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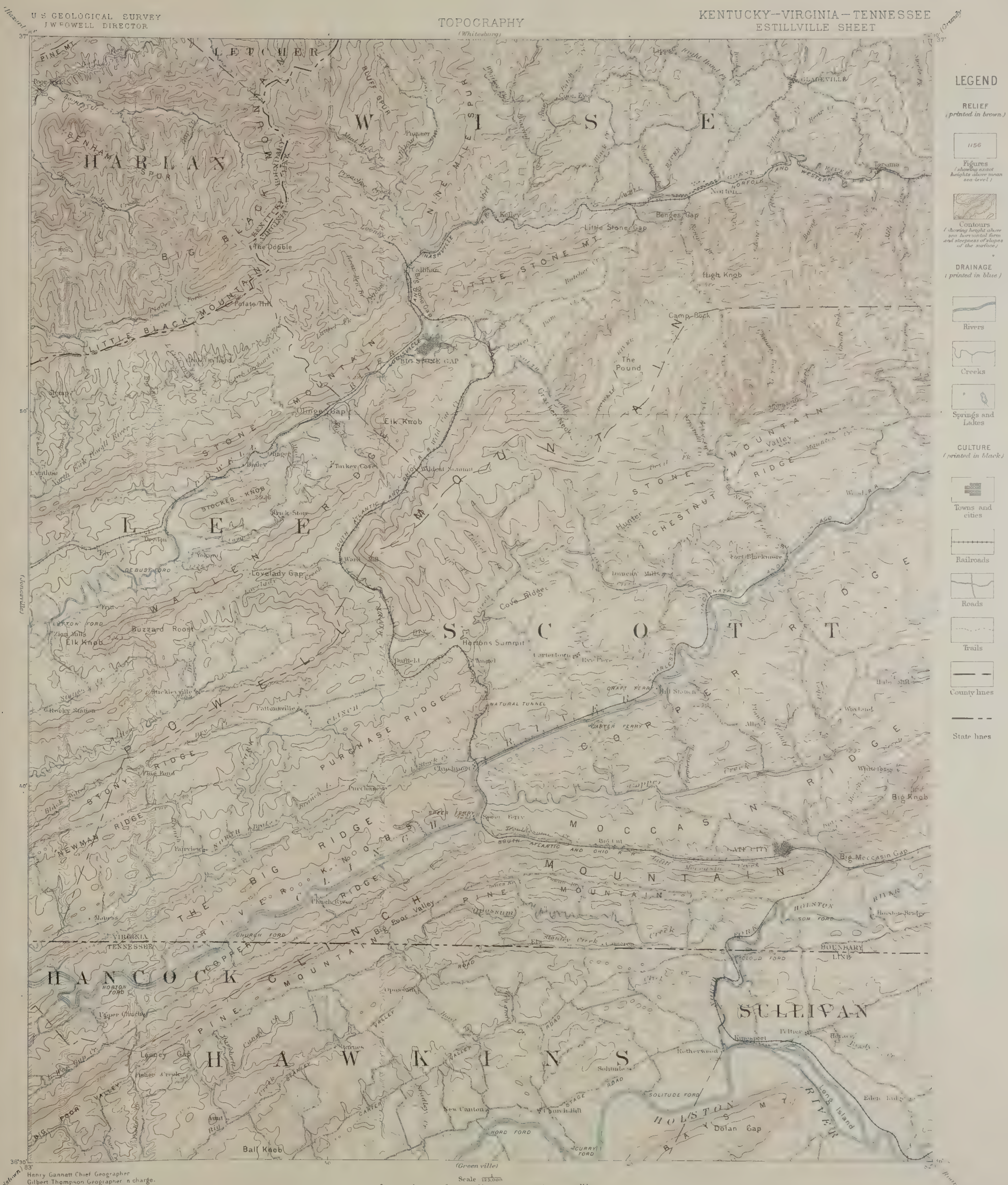
KENTUCKY-VIRGINIA-TENNESSEE
ESTILLVILLE SHEET




Henry Gannett Chief Geographer
Gilbert Thompson Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett
Topography by Morris Bien, F.M. Pearson,
F.J. Knight and A.E. Murlin
Surveyed in 188_-_-8

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

Edition of Mar. 1894

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AREAL GEOLOGY

KENTUCKY—VIRGINIA—TENNESSEE
ESTILLVILLE SHEET


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Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet.

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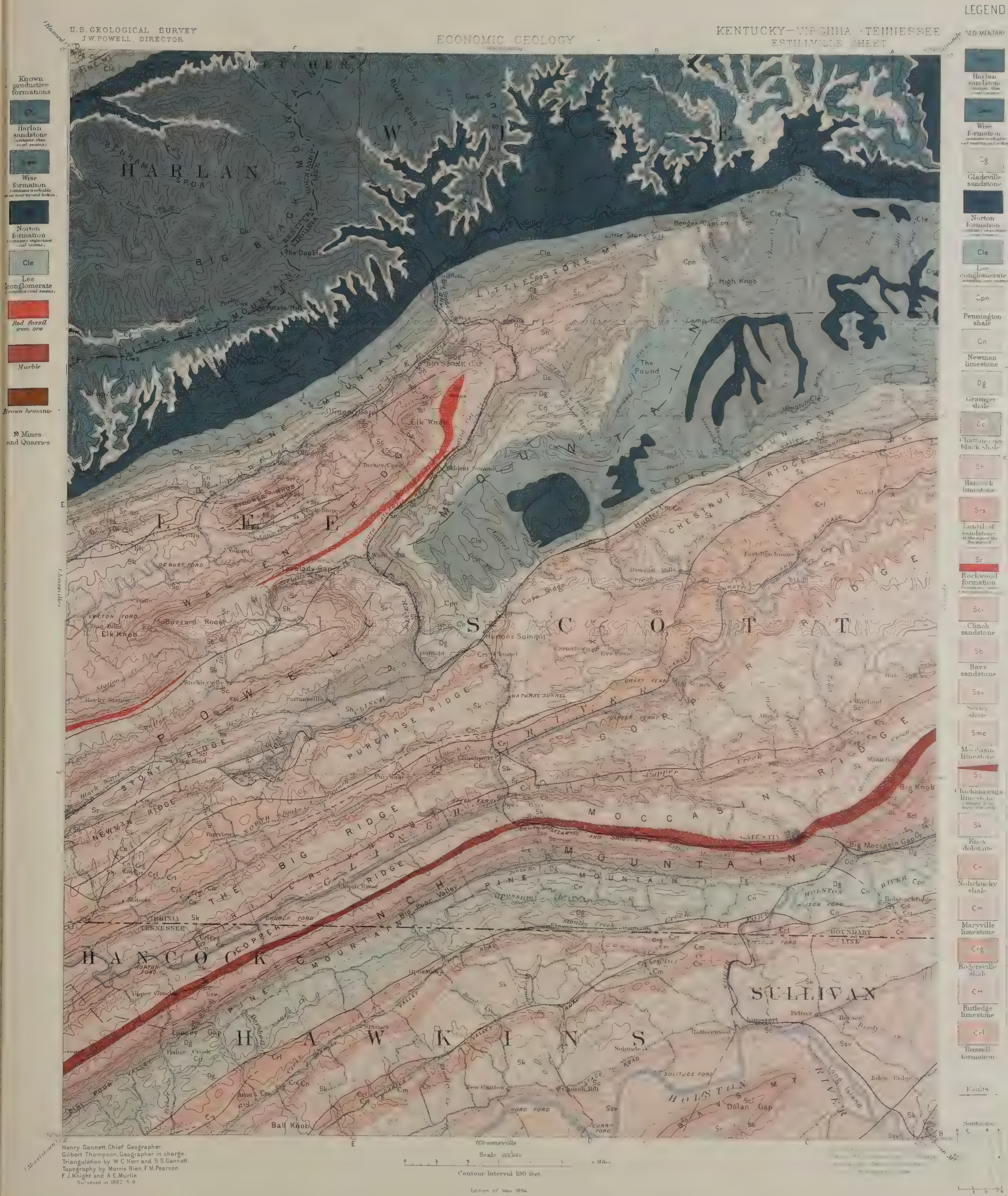
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ECONOMIC GEOLOGY
KENTUCKY—VIRGINIA—TENNESSEE
ESTILLVILLE SHEET
LEGEND
SEDIMENTARY
Known productive formations
Harlan sandstone
Wise formation
Norton formation
Lee conglomerate
Red fossil iron ore
Marble
Brown hematite
Mines and Quarries
Gladeville sandstone
Pennington shale
Newman limestone
Grainger shale
Chattanooga black shale
Hancock limestone
Clinch sandstone
Bays sandstone
Moccasin limestone
Knox dolomite
Nolichucky shale
Maryville limestone
Rogersville shale
Rutledge limestone
Russell formation
Faults
CARBONIFEROUS
DEVONIAN
SILURIAN
CAMBRIAN
HARLAN
WISE
LEE
SCOTT
HANCOCK
HAWKINS
SULLIVAN
LITTLE STONE MT
STONE MOUNTAIN
WALLEN RIDGE
POWELL
PURCHASE RIDGE
NEWMAN RIDGE
CHESTNUT RIDGE
MOCCASIN
BIG RIDGE
CLINCH
The Pound
High Knob
Big Moccasin Gap
Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by Morris Bien, F.M. Pearson
F.J. Knight and A.E. Murlin
Surveyed in 1882-3-8
Contour Interval 100 feet
Edition of May 1894

U.S. GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

STRUCTURE SECTIONS

KENTUCKY-VIRGINIA-TENNESSEE
ESTILLVILLE SHEET


Henry Gannett, Chief Geographer
Gilbert Thompson, Geographer in charge.
Triangulation by W.C.Kerr and S.S.Gannett.
Topography by Morris Bien, F.M.Pearson,
F.J.Knight and A.E.Murlin
Surveyed in 1882-3-8.

(Greeneville)
Scale $\frac{1}{125,000}$
0 1 2 3 4 5 6 Miles
Contour Interval 100 feet

Edition of May 1894.

G.K.Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by Marius R.Campbell
Surveyed in 1891

# COLUMNAR SECTIONS.



## GENERALIZED SECTION NORTH OF CLINCH RIVER.

SCALE: 1000 FEET = 1 INCH.

| Period. | Formation Name. | Symbol. | Thickness in Feet. | Character of Rocks. | Character of Topography. |
|---|---|---|---|---|---|
| CARBONIFEROUS | Harlan sandstone. | Ch | 800 | Coarse, white sandstone with interbedded shale and thin coal seams. The bed of sandstone at the base is particularly heavy. | Caps the summit of Big Black Mountain; forms heavy cliffs and ledges. |
| | Wise formation. | Cws | 1200 | Shale, sandstone, and coal beds. Near the top is a coal horizon containing one or two workable seams, and another occurs in the lower portion carrying several seams of importance. The main body of the formation is generally barren of workable coal beds. | Steep slopes of Big Black and Little Black mountains. |
| | Gladeville sandstone. | Cg | 120 | Coarse, white sandstone, sometimes conglomeratic. | In Wise County forms a mesa, or table-land. |
| | Norton formation. | Cnr | 1270 | Shale, sandstone, and coal, interbedded. Near the top, beds of sandstone predominate, and shales below. In the western portion of the sheet heavy coal beds are limited to the upper part, but in the eastern portion important seams occur in the lower half of the formation. | Valleys or steep hill slopes. |
| | Lee conglomerate. | Cle | 1240-1530 | Massive sandstone. Shale with coal seams. Sandstone, generally free from pebbles, with shaly layers. Shale with coal seams. Coarse conglomerate. | The principal ridge-making member of the Coal Measures. The ridges are extremely rough and rocky, the steepness of the slope depending upon the dip of the rocks. Pine and Stone mountains are the best examples of these ridges. When flat this conglomerate forms mesas. |
| | Pennington shale. | Cpn | 1040-1100 | Red, argillaceous shale. Beds of sandstone and calcareous shale. | Steep slopes and ledges along the conglomerate ridges. |
| | Newman limestone. | Cn | 710-930 | Calcareous shale with beds of impure limestone. Pure, blue limestone, becoming cherty toward the base. | Cliffs or steep slopes, and in exceptional cases low, rounded knobs in the valleys. |
| DEVONIAN | Grainger shale. | Dg | 430-800 | Calcareous sandstone. Sandy shale, merging into the black shale below. | Slopes or low ridges and knobs. |
| | Chattanooga black shale. | Dc | 590-1000 | Black, carbonaceous shale. Ash-colored, micaceous or sandy shale. Black, coal-like, carbonaceous shale. | "Poor valleys," with white and unproductive soil. |
| SILURIAN | Hancock limestone. | Sh | 180-275 | Blue, fossiliferous limestone, very sandy at the top and bottom. | Valleys. |
| | Rockwood formation. | Sr | 280-470 | Sandy shale, sandstone, and red, fossil iron-ore. | Sharp, narrow ridges; "poor valley" ridges or benches on the southern side of the Clinch sandstone ridges. |
| | Clinch sandstone. | Scl | 60-180 | Coarse-grained, white sandstone. | Sharp, mountainous ridges. |
| | Bays sandstone. | Sb | 0-325 | Red sandstone and sandy shale. | Steep slopes. |
| | Sevier shale. | Ssv | 440-675 | Sandy shale. Yellow, calcareous shale. | Steep slopes and irregular spurs. |
| | Chickamauga limestone. | Sc | 1700-3800 | Blue, flaggy limestone, becoming more massive toward the base. In its lower portion occur extensive lentils of red and gray marble, below which the formation generally contains black cherts. | Broad and level valleys; rich farming country. |
| ? | Knox dolomite. | Sk | 2100-2300 | Magnesian limestone; the top is characterized by white, argillaceous limestone, below which the rock is generally gray and at certain horizons very cherty. | Low, rounded knobs or ridges, generally covered with a mantle of residual clay and cherts. |
| CAMBRIAN | Nolichucky shale. | Єn | 525 | Calcareous shale, carrying lentils of blue limestone. | Gentle slopes. |
| | Maryville limestone. | Єm | 500-600 | Massive blue limestone. | Slopes or irregular valley lands. |
| | Rogersville shale. | Єrg | 110 | Blue, calcareous shale. | Gentle slopes. |
| | Rutledge limestone. | Єrt | 260 | Impure magnesian limestone. | Low ridges in the valleys. |
| | Russell formation. | Єrl | 1000+ | Generally from 400 to 600 feet of brown, sandy shale at top, followed by thin-bedded sandstone, ferruginous limestone, and sandy shale of unknown thickness. | Knobs and ridges where sandstones prevail, and valleys where the shale is present. |

## GENERALIZED SECTION SOUTH OF CLINCH RIVER.

SCALE: 1000 FEET = 1 INCH.

| Period. | Formation Name. | Symbol. | Thickness in Feet. | Character of Rocks. | Character of Topography. |
|---|---|---|---|---|---|
| CARBONIFEROUS | Newman limestone. | Cn | 1500 | Argillaceous limestone, interbedded with calcareous shale and sandstone. This becomes purer toward the base, with gray crystalline limestone that carries some chert. | Rolling valley lands, deeply and sharply cut where streams are actively corrading their channels. |
| DEVONIAN | Grainger shale. | Dg | 600-980 | Black, calcareous shale at the top, graduating into sandy shale and sandstone. | Sharp ridges. |
| | Chattanooga black shale. | Dc | 500 | Black, carbonaceous shale. Ash-colored, micaceous or sandy shale. Black, carbonaceous shale. | "Poor valleys;" white, poor soil. |
| SILURIAN | Hancock limestone. | Sh | 0-30 | Blue limestone, becoming cherty toward the top. | Slopes of Clinch ridges. |
| | (Rockwood sandstone.) Rockwood formation. | (Srs) Sr | 20-120 | Coarse sandstone or conglomerate. Sandy shale. | Slopes of Clinch ridges. |
| | Clinch sandstone. | Scl | 300-500 | Coarse, white sandstone, containing locally a few beds of red shale. | Sharp, mountainous ridges. |
| | Bays sandstone. | Sb | 125-375 | Red sandstone. | Steep slopes. |
| | Sevier shale. | Ssv | 1400-4000 | Yellow or blue, calcareous shale, which, toward the southeast, becomes quite sandy in its upper part. | Steep slopes or knobs. |
| | Moccasin limestone. | Smc | 0-500 | Red, argillaceous limestone. | Slopes |
| | Chickamauga limestone. | Sc | [illegible]-1250 | Blue limestone with lentils of red, mottled marble. | Rolling valley land |
| ? | Knox dolomite. | Sk | 2100-2900 | Gray or white magnesian limestone, generally quite cherty. | Low, rounded ridges, generally covered with a mantle of residual clay and cherts. |
| CAMBRIAN | Nolichucky shale. | Єn | 450-730 | Yellow, calcareous or sandy shale, containing a heavy lentil of blue limestone. | Gentle slopes or knobs |
| | Maryville limestone. | Єm | 560-[illegible] | Massive gray limestone that in places contains very heavy, nodular cherts. | Low ridges or slopes. |
| | Rogersville shale. | Єrg | 0-220 | Blue, calcareous shale. | Valleys. |
| | Rutledge limestone. | Єrt | 240 | Impure magnesian limestone. | Valleys. |
| | Russell formation. | Єrl | 1600+ | Brown shale at the top, grading through sandy shale into sandstone; with beds of limestone. | Knobs or ridges. |

## NAMES OF FORMATIONS.

| Period. | Names and Symbols used in this Folio. | | Safford: Geology of Tennessee, 1869. | Stevenson: A Geological Reconnaissance in part of Lee, Wise, Scott, and Washington Counties, Va., 1881. |
|---|---|---|---|---|
| Carboniferous | Harlan sandstone. Wise formation. Gladeville sandstone. Norton formation. Lee conglomerate. | Ch Cws Cg Cnr Cle | Coal Measures. | Coal Measures. Quinnemont or Seral conglomerate. |
| | Pennington shale. Newman limestone. | Cpn Cn | Mountain limestone. Siliceous group. | Mountain limestone. Siliceous group. |
| Dev. | Grainger shale. Chattanooga black shale. | Dg Dc | Black shale. | Chemung and Hamilton. |
| Silurian | Hancock limestone. | Sh | Meniscus limestone. | Oriskany and Lower Helderberg |
| | Rockwood formation. | Sr | Dyestone group. | Clinton group. |
| | Clinch sandstone. Bays sandstone. | Scl Sb | Clinch Mountain sandstone. | Medina sandstone. |
| | Sevier shale. Moccasin limestone. Chickamauga limestone. | Ssv Smc Sc | Trenton and Nashville series. | Trenton and Nashville group. |
| | Knox dolomite. | Sk | Knox dolomite. | Knox dolomite. |
| Cambrian | Nolichucky shale. Maryville limestone. Rogersville shale. Rutledge limestone. | Єn Єm Єrg Єrt | Knox shale. | Knox shale. |
| | Russell formation. | Єrl | Knox sandstone. | Knox sandstone. |

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales;* but when rocks of any class are found in thin layers that are due to pressure they are called *slates.* When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists,* a term which applies to both shaly and slaty structures.

Rocks of any period of the earth's history, from the Neocene back to the Algonkian, may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known remain in some localities essentially unchanged.

Metamorphic crystalline formations are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines.

If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters only.

## USES OF THE MAPS.

*Topography.*—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

*Areal geology.*—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its colored pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

*Economic geology.*—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors.

A symbol for mines is introduced in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

*Structure sections.*—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial cutting which exhibits those relations is called a *section,* and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure,* and a section exhibiting this arrangement is called a *structure section.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows the underground relations of the rocks. The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

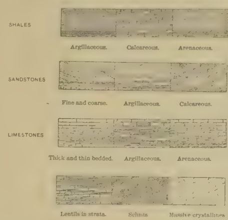


Fig. 3. Symbols used to represent different kinds of rocks

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thicknesses can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable.*

The second group of formations consists of strata which form arches and troughs. These strata were continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first group, being parallel, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata or upon their upturned and eroded edges, the relation between the two is *unconformable,* and their surface of contact is an *unconformity.*

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only relations which actually occur. The sections in the Structure Section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

*Columnar sections.*—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram. The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,

*Director.*